Description

Light-emitting semiconductor component comprising a protective diode

The invention relates to a light-emitting semiconductor component as claimed in the preamble of claim 1.

The present patent application claims the priority of German Patent Applications 102004005269.7 and 10356283.4, the content of the disclosure of which is herewith incorporated by reference.

The increasing miniaturization of opto-electronic components and special requirements, particularly with regard to the threshold current and the radiation quality, lead to the radiation-emitting active area of such components frequently being constructed to be relatively small. On the other hand, it is known that a relatively small active area produces increased sensitivity of the component to electrostatic discharges (ESD). Such ESD voltage pulses can impair the operation of an opto-electronic component or even destroy it.

From US 6 185 240 B1, a vertical cavity surface emitting laser (VCSEL) is known which contains a protective diode integrated monolithically on the semiconductor substrate for increasing its ESD resistance. This protective diode is connected in antiparallel with the VCSEL by means of a multi-stage etching process and suitable running of the contact metallizations and in this manner protects the VCSEL from ESD voltage pulses which occur in the reverse direction of the pn junction of the VCSEL.

A further radiation-emitting semiconductor component with improved ESD immunity is known from DE 199 45 134 A1. In this component, a monolithically

integrated protective diode is implemented by providing a part of the pn junction with a Schottky contact. The part-section provided with the Schottky contact is connected in parallel with the light-emitting section and has the same forward direction. Due to a steeper current/voltage characteristic, the current preferably flows through the protective-diode section at high voltages in the forward direction. In this manner, this component is protected against ESD voltage pulses in the forward direction.

The invention is based on the object of specifying a light-emitting semiconductor component which is distinguished by an improved protection against ESD voltage pulses in the reverse direction of the light-emitting pn junction and can be produced with relatively little expenditure.

This object is achieved by a light-emitting semiconductor component having the features of claim 1. Advantageous embodiments and developments of the invention are the subject-matter of the dependent claims.

According to the invention, a light-emitting semiconductor component contains a monolithically produced sequence of semiconductor layers, wherein an area of n-doped semiconductor layers and an area of p-doped semiconductor layers follow one another and a first pn junction is formed between the areas, the first pn junction being subdivided into a light-emitting section and a protective-diode section by an insulating section. The insulating section electrically insulates the light-emitting section and the protective-diode section from one another in the area of the p-doped semiconductor layers. In the area of the protective-diode section, an n-doped layer is applied to the area of the p-doped semiconductor layers which is electrically conductively connected to the area of

the p-doped semiconductor layers of the light-emitting section and forms a second pn junction with the p-doped area of the protective-diode section. The protective-diode section has a larger area than the light-emitting section.

Accordingly, a first pn junction and a second pn junction are connected in series with opposite polarity in the protective-diode section. These series-connected pn junctions in turn are connected in parallel with the pn junction of the light-emitting section. In the case of a voltage applied in the forward direction of the first pn junction, for example the operating voltage of the light-emitting component, the second pn junction is polarized in the reverse direction in the protective-diode section. The current therefore essentially only flows through the light-emitting section.

If, in contrast, a voltage is applied to the semiconductor component in the reverse direction of the first pn junction, the second pn junction is polarized in the forward direction in the protective-diode section. In this case, the first pn junction is polarized in the reverse direction both in the light-emitting section and in the protective-diode section. In the case of an ESD voltage pulse in the reverse direction which exceeds a breakdown voltage of the first pn junction, the current preferably flows through the protective-diode section since the latter has a larger area than the light-emitting section. As a result, the risk of damage or destruction of the first pn junction, which is particularly sensitive due to its small area, in the light-emitting section is advantageously reduced.

In the context of the invention, the area of the first pn junction in the protective-diode section and in the light-emitting section, respectively, is understood to be the area available for a current flow between

electrical contacts of the component in the plane of the boundary face between the p-doped area and the n-doped area of the first pn junction. When these areas are determined, area components should not be taken into consideration through which a current flow is prevented, for example due to insulating areas provided for spatial current limiting in the sequence of semiconductor layers.

The area of the first pn junction is preferably larger in the protective-diode section than in the light-emitting section at least by a factor of 100. In this case, the current essentially flows through the protective-diode section in the case of an ESD voltage pulse.

An advantage of the light-emitting semiconductor component according to the invention consists in that the layer structure can be produced relatively simply. For example, no etching processes are required which extend from the surface of the sequence of semiconductor layers to the surface of the substrate since the light-emitting section and the protective-diode section only need to be insulated from one another in the area of the p-doped semiconductor layers.

The emission wavelength of the light-emitting semiconductor component is not restricted to the visible spectral range in the invention. In particular, the emission can also take place in the infrared or ultraviolet spectral range.

The sequence of semiconductor layers is applied, for example, to a semiconductor substrate. However, it is also possible that a growth substrate originally used for growing the sequence of semiconductor layers is detached. For the purpose of contacting the light-emitting component, a first contact metallization is

applied to a side of the semiconductor substrate facing away from the sequence of semiconductor layers and a second contact metallization is applied to part-areas of the surface of the light-emitting section opposite to the semiconductor substrate, for example.

The insulating section extends, for example, from the top of the sequence of semiconductor layers into the area of the n-doped layers. The n-doped areas of the light-emitting section and of the protective-diode section are thus not interrupted by the insulating section, at least in parts.

The light-emitting section can be formed, in particular, by a vertical cavity surface emitting laser (VCSEL). The laser resonator of the VCSEL is formed, for example, from a first sequence of Bragg reflector layers and a second sequence of Bragg reflector layers, each of which has a multiplicity of layer pairs, the first pn junction being arranged between the two Bragg reflectors and one of the two Bragg reflectors being semitransparent for the laser radiation generated in the pn junction.

Preferably, at least one current aperture, by means of which the current flowing through the active area of the light-emitting section is spatially limited, is provided in one of the two sequences of Bragg reflector layers. Applying this measure, in particular, the beam cross section can be narrowed and the threshold current density can be reduced.

The insulating section is constructed, for example, as a trench so that the light-emitting section and the protective-diode section have a mesa-shaped structure on the side of the trench. The trench is produced, for example, by an etching process or by mechanical microstructuring. The inside of the trench is advantageously provided with an insulating layer. The

second contact metallization can be applied after the generation of the trench in this case and the trench can be filled up with the material of the second contact metallization without the trench losing its insulating effect.

In the text which follows, the invention will be explained in greater detail by means of an exemplary embodiment.

Figure 1 shows a diagrammatic cross section through a light-emitting semiconductor component according to the invention; and

Figure 2 shows an equivalent circuit of the semiconductor component shown in Figure 1.

The light-emitting semiconductor component shown in Figure 1 is a vertical cavity surface emitting laser (VCSEL). The VCSEL contains a substrate 1 to which is applied a sequence of semiconductor layers 2. The sequence of semiconductor layers 2 contains an area of n-doped layers 3 and an area of p-doped semiconductor layers 4 between which a first pn junction 5a, 5b is formed. The pn junction 5a, 5b is subdivided into a light-emitting section 7 and a protective-diode section 8 by an insulating section 6. The area of the first pn junction 5b in the protective-diode section 8 is larger, preferably larger by more than a factor of 100, than the area of the first pn junction 5a in the light-emitting section 7.

The pn junction 5a in the light-emitting section 7 represents the active zone of the VCSEL. The area of n-doped semiconductor layers 3 and the area of p-doped semiconductor layers 4 contain Bragg reflectors which in each case contain a multiplicity of reflecting layer pairs (not shown). The Bragg reflectors form the laser resonator of the VCSEL. The Bragg reflector facing the

surface of the VCSEL in the area of the p-doped semiconductor layers 4 is constructed to be semitransparent for coupling out the laser radiation 18.

The electrical contacting of the VCSEL is implemented by a first contact metallization 11 on the side of the substrate 1 facing away from the sequence of semiconductor layers 2 and a second contact metallization 12 on the surface of the sequence of semiconductor layers 2. The surface of the light-emitting section 7 is only partially covered by the second contact metallization 12, leaving a light exit opening 17. The surface of the light-emitting section 7 in this area is preferably provided with an insulating layer 16 which protects the surfaces of the semiconductor layers, in particular, against oxidation or other environmental influences.

The current flowing through the light-emitting section 7 is advantageously limited to a central area 15 by a current aperture 14. The current aperture 14 can be constructed, in particular, in the area of the p-doped semiconductor layers 4. For example, a semiconductor layer containing aluminum, particularly AlAs, in which part-areas 14 are oxidized, exists in this area 4. The oxidized areas 14 act in an insulating manner so that the current flow is restricted to a central area 15. A current aperture 14 can also exist in the protective-diode section 8. Although it is not desirable to limit the area available for the current flow in this section, a production of the current aperture on both sides of the trench 19 can simplify the production process. In this case, the area of the current aperture 14 should be much larger in the protective-diode section 8 than in the light-emitting section 7.

The insulating section 6 is constructed, for example, as a trench 19 which extends from the surface of the

semiconductor layers 2 into the area of the n-doped semiconductor layers 3. The p-doped areas 4 of the light-emitting section 7 and of the protective-diode section 8 are separated from one another and electrically insulated by the trench 19. The area of n-doped semiconductor layers 3, in contrast, is interrupted by the trench 19, at least not completely, so that the light-emitting section 7 and the protective-diode section 8 are electrically connected to one another in this area. The trench 19 forming the insulating section 6 can be produced, for example, by an etching process or mechanical machining. On its inside, the trench 19 is advantageously provided with an insulating layer 16. This ensures that when the second contact metallization 12 is applied, no short circuit occurs between the light-emitting section 7 and the protective-diode section 8. Before the insulating layer 16 is applied, the current apertures 14 can be produced from the inside of the trench 19 by an oxidation process.

Instead of constructing the insulating section 6 as trench 19, it is also possible, as an alternative, that the insulating section 6 is produced by implantation or diffusion of foreign matter into the sequence of semiconductor layers 2 or by oxidation of a part of the sequence of semiconductor layers 2.

In the area of the protective-diode section 8, an n-doped semiconductor layer 9 is applied to the surface of the area of the p-doped semiconductor layers 4. Between these, a second pn junction 10 is formed. To the n-doped semiconductor layer 9, a bond pad 13 provided for the electrical contacting of the VCSEL is applied which is connected electrically conductively to the second contact metallization 12. In the area of the protective-diode section 8, the first pn junction 5b and the second pn junction 10 are connected in series. The light-emitting section 7 and the protective-diode

section 8 are connected in parallel by means of the first contact metallization 11 and the second contact metallization 12 or the bond pad 13, respectively.

This is illustrated by the equivalent circuit shown in Figure 2. The left-hand side of the equivalent circuit corresponds to the light-emitting section 7 and the right-hand side to the protective-diode section 8. The light-emitting section 7 only contains the first pn junction 5a. This is also contained in the protective-diode section 8 but the second pn junction 10 is connected in series with it in opposite polarity.

When the VCSEL is operated, the operating voltage is present at the contacts 20, 21 in the forward direction of the first pn junction 5a, 5b. The second pn junction 10 in the protective-diode section 8 is polarized in the reverse direction in this case so that the current essentially only flows through the light-emitting section 7. In the case of an ESD voltage pulse in the reverse direction of the first pn junction 5a, 5b, the second pn junction 10 is polarized in the forward direction, in contrast, so that the electrical resistance of the protective-diode section 8 is essentially determined by the resistance of the first pn junction 5b. Since the area of the first pn junction 5b in the protective-diode section 8 is larger than the area of the first pn junction 5a in the light-emitting section 7, a reverse current caused by the voltage pulse essentially flows through the first pn junction 5b in the protective-diode section 8. As a result, the first pn junction 5a in the light-emitting section 7, provided for generating radiation, is protected from damage by the voltage pulse. The greater the ratio of the area of the first pn junction (5a, 5b) in the protective-diode section 8 to the area in the light-emitting section 7, the better the protective effect.

The first pn junction 5b in the area of the protective-diode section 8 can be short circuited in a further embodiment of the invention. This is possible, for example, due to an electrically conductive layer (not shown in Figure 1) which is applied to a side edge of the sequence of semiconductor layers 2 facing the protective-diode section 8 and electrically connects the area of n-doped semiconductor layers 3 and the area of p-doped semiconductor layers with one another. In this embodiment, in the case of an ESD voltage pulse in the reverse direction, the current does not flow through the first pn junction 5b but through the electrically conductive layer and the second pn junction 10. In consequence, this embodiment does not require the area of the first pn junction 5b in the protective-diode section 8 to be larger than the area of the first pn junction 5a in the light-emitting section 7.

In the context of the invention, it is possible for the specified conduction types p and n of the semiconductor layers to be exchanged with one another in each case. In this case, all conduction types p and n mentioned in the description are to be considered to be exchanged with one another.

Naturally, the explanation of the invention by means of the exemplary embodiment must not be considered as a restriction to the latter. Instead, the invention includes the features disclosed, both individually and in any combination with one another even if these combinations have not been specified explicitly in the claims.